APPLICATION FOR PATENT

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Title: Lock for a Downhole Tool with a Reset Feature

FIELD OF THE INVENTION

[0001] The field of the invention is locks for downhole tools that can selectively retain the tool in a position for a particular operation and more particularly locks that can be released and subsequently reset for holding a downhole tool for subsequent operations.

BACKGROUND OF THE INVENTION

[0002] There are many types of tools used downhole. Some tools are moved repeatedly between positions for the performance of different operations. While these tools are designed to shift between the positions to accomplish downhole functions, the procedures downhole vary with time and tools that readily performed functions in multiple positions reveal a potential shortcoming. One such shortcoming can be the inability to retain a desired position throughout the duration of a particular downhole operation. In the past, locking the tool in a particular position has been tried, but those attempts created additional operating limitations. Some locks were effective against pressure variations but were not effective in resisting mechanical impacts. Some locks, when actuated hydraulically, permanently held a position of the downhole tool and could not be released.

[0003] What was needed was a lock for a downhole tool that could fix its position for a time to allow a certain procedure to take place and that could thereafter be released to allow the tool to operate in its various positions for other purposes.

[0004] The context that suggested such a desired lock assembly was a downhole tool known as a downhole valve and more specifically a model 'RB' Valve offered by Baker Hughes Incorporated. This downhole valve featured a J-slot mechanism between a sleeve and a mandrel. Pressure in the tubing could be cycled back and forth enough times

to operate the J-slot mechanism until the mandrel, upon relief of applied pressure after a predetermined amount of cycles, could move a certain distance to allow the valve to go to the open position. In this example the valve was a ball that rotated 90°. Since this valve was actuated with pressure cycles in the tubing, it could be affected by pressure spikes in the tubing. Also, it was susceptible to mechanical impacts on the mandrel that could operate the valve out of the desired position for a specific procedure. One way this could happen is a tool string running through the mandrel could drag it to the next indexing position. Competing valves that operated on hydraulic cycling in combination with a J-slot mechanism would allow the valve to go to the open position and be locked there, but the lock was permanent so the valve could not later be closed.

[0005] Some operators, particularly in deep water, have high cost completions that need a lock that can be reset to allow injection of fluids through an open valve at high rates without concern that such a procedure will operate the valve out of an open position. Additionally, such a re-settable lock could accommodate tool strings with tight clearances to pass through without risk of moving the valve out of the desired position. Such a lock would then allow the valve position to be shifted when the specific operation that required the valve position to be locked is concluded.

[0006] Those skilled in the art will more readily appreciate the multiple applications of the described preferred embodiment below in a variety of downhole applications. In the preferred embodiment, the lock can hold members that otherwise move relatively with respect to each other when the tool changes positions to perform different functions. The relative movement can occur in one or more directions.

[0007] Many tester valves operate with annulus pressure cycles and are not vulnerable to tubing pressure spikes. The 'RB' Valve has some similar operating characteristics to tester valves except that it cycles on application of tubing pressure. Tester valves with J-slot mechanisms are illustrated in U.S. Patent 4,667,743. A hydraulically triggered resetting lock for a tester valve that selectively disables the drive system for the mandrel is shown in U.S. Patent 5,518,073. In this device, the valve can stay in the open position even with subsequent pressure cycling that can unintentionally

occur. The mandrel is not mechanically restrained, rather, it is simply temporarily disabled from being further actuated by applied pressure until the drive system is again enabled. Also of related interest are U.S. Patent 4,403,659 and U.S. application 2002/0066573. U.S. application 2002/0112862 shows a tester valve that can be cycled a predetermined number of times before it locks permanently closed. One way this occurs is a ratchet lock as shown in Figure 10 and another is with a collet that can jump a hump in only a single direction as shown in the lower end of the split view in Figure 20.

[0008] Also of interest is U.S. Patent 3,762,471 that uses dual control lines and a rotating ball in a subsurface safety valve that may be locked open when a sleeve attached to the ball is forced to move under hydraulic pressure so that the ball moves into the open position and a latch is also forced by hydraulic pressure to move to lock a detent into a recess. The lock can be released by pressure applied to different ports to liberate the detent from the recess. This complex design requires two control lines and due to its complexity was difficult to manufacture economically and was not commercially successful. It also required independent movement of a latch apart from the member that operates the ball to the open position to accomplish the locking. Also related to this design is U. S. Patent 4,550,780 that featured a ball type subsurface safety valve that could be locked open and released. This valve was capable of being unlocked by pressure applied to the tubing and for that reason could be subject to being unlocked by unexpected pressure surges in the tubing. Locking also required the insertion of a bridge. plug.

SUMMARY OF THE INVENTION

[0009] The lock allows two members in a downhole tool to be temporarily held together. In an application where mandrel movement is dictated by pressure cycling in combination with a J-slot mechanism, such as in a downhole valve, the mandrel is releaseably retained to an adjacent connector against mechanical impacts. The mandrel features an extended collet that moves relatively to a floating sleeve during pressure cycles. At some point the collet heads rise to an elevated groove that causes them to

contact a no-go shoulder for locking. The lock is defeated be removing the collet heads from the elevated groove for normal tool operation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figures 1a-1b are a sectional view of the lock components with the downhole tool, in this example a valve, in the closed position;

[0011] Figures 2a-2b are the view of Figure 1 with the valve still closed but with pressure applied during an intermediate cycle;

[0012] Figures 3a-3b are the view of Figure 2 with the pressure removed but the valve is still closed;

[0013] Figures 4a-4b are the view of Figure 3 with pressure reapplied causing the collet heads to jump from the upper groove to the lower groove and pass over the raised groove;

[0014] Figures 5a-5b show the pressure removed to put the valve in the open position and secure the lock with the collet heads on the raised groove; and

[0015] Figures 6a-6g show a split view of an 'RB' Valve using the lock of the present invention with the valve open and locked on one side and at the instant of release on the other.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0016] The drawings illustrate the resetting lock mechanism in detail and omit most of the details of the operation of a tester valve that are known. While an 'RB' valve is used for illustrative purposes, the present invention can be deployed in a downhole application where it is desired to hold one member to another during a specific downhole operation and to allow the downhole tool to resume other operations at a later time.

[0017] In the preferred embodiment, the invention is deployed in an 'RB' Valve. Such a valve is frequently attached to a packer and employs a j-slot mechanism, which is

cycled by virtue of alternating application and removal of pressure downhole. In the preferred embodiment, pressure cycling occurs in the tubing and the pressure cycles, after a predetermined number of cycles, allows a mandrel **10** to shift with respect to a stationary surrounding connector **12** so that the net result can be an alignment or misalignment of ports to selectively open or close the downhole valve. In normal operations of the downhole valve a certain number of pressure cycles will advance a pin in a J-slot, effectively shifting the mandrel **10** up and down each time but not far enough to change the valve position. In the preferred embodiment, the pressure cycles need to be repeated a predetermined number of times before release of the pressure will allow the valve to open. At this point the mandrel stays in the open position and is insensitive to pressure cycles in the tubing from subsequent operations. However, without the lock of the present invention such a valve was still susceptible to closing from mechanical impacts resulting from subsequent downhole operations through the mandrel. If it was possible to build a tubing/annulus pressure differential with the valve open, without the present invention, such as might occur if injecting through the valve at high flow rates, then the valve might partially close. At the same time, prior solutions that automatically locked a hydraulically functioned J-slot type downhole valve proved to be of limited use due to their inability to be re-closed. Accordingly, in the preferred embodiment, the lock provides the versatility of locking in the open position and preferably automatic lock actuation when achieving that position in combination with the ability to unlock so the valve can be returned to normal function where it can be closed and opened any number of times as conditions downhole require.

[0018] The workings of the lock of the present invention can be seen starting with Figure 1. The mandrel **10** is operated by the J-slot mechanism (not shown) to move up and down. Those skilled in the art will appreciate that the mandrel **10** has a central axis **14** and it moves up and down responsive to pressure cycles, preferably in the annular space above the packer or other seal (not shown). The mandrel **10** is operated by a set of pistons and reciprocates but does not rotate. The reciprocating movement is controlled by a rotating sleeve with pins that travel in a J-Slot pattern in the mandrel. **10**. Attached to mandrel **10** at thread **16** is a collet ring **18** that has extending collet fingers **20** with each finger **20** having a collet head **22**. The collet ring **18** is biased uphole by a spring **42**.

While the mandrel is mounted so that it can reciprocate responsive to applied pressure cycles, the surrounding connector **12** is fixedly mounted from the packer or seal above (not shown). Mounted between the connector **12** and the mandrel **10** is sleeve **26**. The upper travel limit of sleeve **26** is defined by ring **28** attached at thread **30** to connector **12**. The lower travel limit of sleeve **26** happens when a protrusion **32** also known as a no-go and which extends in a direction away from the axis **14** contacts a no-go **34** on connector **12** that is pointing toward the axis **14**. Because of the connection at thread **16** the collet heads **22** move in tandem with mandrel **10**. However, relative movement between the sleeve **26** and the mandrel **10** is possible if the sleeve is restrained by contact of no-go **32** with no-go **34**.

[0019] Sleeve **26** has an upper groove **36**, a lower groove **38** and a raised groove **40** between them. The collet heads **22** can travel past no-go **34** when they are aligned with either grooves **36** or **38**. However, when the collet heads are aligned with raised groove **40** they can't clear no-go **36**. When this happens, the lock **L** is operational. The lock L can be defeated by using a tool to liberate the mandrel **10** to move uphole under the force of spring **42**.

[0020] It should be noted that sleeve **26** differs in design between the version shown in Figures 1-5 and that shown in Figure 6. The design in Figure 6 shows a greater wall thickness under raised groove **40** and is used primarily in the larger sizes. The added wall thickness is for added strength to deal with the anticipated loads imposed from collet heads **22** to prevent the sleeve **26** from deforming in that location under load. This feature is not found in the sleeve design of Figures 1-5 because in the smaller sizes the loads are lower thus avoiding the need for increasing the wall thickness under the raised groove **40**.

[0021] Sleeve **26** is thicker at upper end **44** to give it strength against impact loads on the mandrel **10** with the no-go shoulders **32** and **34** in contact. Additionally, sleeve **26** has a small diameter **46** that extends into recess **48** to guide the movement of sleeve **26** and to prevent it from contorting if no-go shoulders **32** and **34** contact violently.

[0022] The operation of the lock **L** will now be described in detail. In Figure 1 the tester valve (not shown) is in the closed position and no pressure is applied to the tubing. The sleeve **26** is against ring **28** and the collet heads **22** are in groove **36**.

[0023] The procedure for opening the valve requires cycles of pressure to the tubing. In a particular design it may take 11 cycles of pressure where each time pressure is applied the lock **L** will go into position as shown in Figure 2. In Figure 2, the mandrel **10** has shifted down compared to the figure 1 position. The collet heads **22** remain in upper groove **36,** as there has been no relative movement between the mandrel **10** and the sleeve **26**. The collet heads **22** have cleared no-go **34** on the connector **12**.

[0024] When the pressure is released in each of the 11 cycles referred to above, springs **42** and **58** urge the mandrel **10** uphole and up with it go the collet heads **22** still in upper groove **36**. The collet heads do not rise above no-go **34** but as previously mentioned, when they are in groove **36** they are capable of clearing no-go **34**.

[0025] Figure 4 shows what happens on the last cycle (cycle12, in the preferred embodiment) where the downhole valve will open. In the first part of this cycle, the tubing pressure is applied forcing the mandrel **10** down. This time the J-slot mechanism (not shown) allows the mandrel **10** to move down further than before. The excess movement of mandrel **10** also means that collet heads **22** move a similar amount. However, the no-goes **32** and **34** contact, preventing downward movement of sleeve **26**. As a result the collet heads **22** are pulled down with respect to sleeve **26** until they land in lower groove **38**. The collet heads **22** have jumped over the raised groove **40**.

[0026] When the tubing pressure is released, the J-slot mechanism (not shown) will let the mandrel move uphole under the force of spring **42**. The collet heads **22** stay in the lower groove **38** taking the sleeve **26** uphole with mandrel **10**. Eventually, after collet heads **22** clear the no-go **34**, the sleeve **26** comes up against ring and its upward movement is stopped. However, in this cycle, the J-slot mechanism (not shown) lets the mandrel **10** keep moving up to expand the collet heads **22** apart as they jump up on raised groove **40**. This is the position shown in Figure 5. In this position, the mandrel has moved up enough to open the valve (not shown) and the mandrel **10** is precluded from moving

down because collet heads **22** will not clear no-go **34**.when on raised groove **40**.At the same time, spring **42** keeps the mandrel **10** from moving uphole as the spring force keeps mandrel **10** up against a stop (not shown).

[0027] The lock **L**, in the preferred embodiment, is automatically triggered as the downhole valve goes into the open position. The lock **L** can be defeated by inserting a tool that extends the mandrel **10** by shifting dogs (not shown) in a manner that lets the lower end of mandrel **10** (not shown) be forced down to close the valve while allowing the portion of mandrel **10** shown in Figure 5 be biased up by spring **42** with collet heads **22** moving relatively to sleeve **26** so that the collet heads **22** go into upper groove **36** so that the position of Figure 1 is resumed. The downhole valve can now be cycled the 12 times mentioned before to get it to open and lock open as described above.

[0028] The release procedure is illustrated in an 'RB' valve shown in Figure 6. Figure 6 is a split view showing the 'RB' valve locked open on one side and at the instant of release on the other. The release is accomplished by an inserted release tool **T**, shown schematically in the release position as **T'**, that grabs dog **50** shown in Figure 6c and moves it to a position **50'**. When that happens, a collet **52** in Figure 6d loses support from sleeve **54** when it moves up with dog **50**. The lower portion **56** of mandrel **10** now can be biased down by spring **58** push down the actuating mechanism **60** to rotate ball **62** into the closed position from the open position shown in Figure 6f. At the same time, because collet **52** is undermined, the upper portion **62** of mandrel **10** can be pushed up by spring **42** far enough so that collets **22** can return to upper groove **36**. This amount of upward movement is permitted by the J-slot assembly **64**. Other release techniques are also envisioned. It should be noted that spring 24 causes collet **52** to be subsequently captured by sleeve **54** as the J-slot mechanism **64** is thereafter cycled to begin the process of reopening the valve.

[0029] Those skilled in the art can appreciate that the lock **L** can be used in a variety of applications downhole where it is desired to temporarily hold a movable member in one position relative to a fixed member. The movable member can be actuated in a variety of ways and can exhibit longitudinal movement, rotational movement or a

combination of such movements. The lock can be triggered to come on at predetermined positions of the moving member. This can be made to occur at either extreme of the movement range of the movable member or any point or points in between. The lock **L** can be automatically deployed at a predetermined position. The lock can preferably be released in a variety of ways and preferably in a non-destructive manner, which will allow it to function again without a trip out of the hole. The lock **L** is preferably of simple construction to assure reliable operation even in hostile environments. In the preferred embodiment, it requires no pistons or additional seals to be operative. In preferred embodiment, the locking can occur either without rotation of the locking components or, if there is rotation, the locking can occur independently of the degree of rotation of any of the components. While the lock **L** is particularly suitable for temporarily locking open a downhole valve automatically when it reaches an open position, it can be used in other ways on tester valves or other downhole tools, as partially described above.

[0030] The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made without departing from the invention.